LOWERING STRENGTH OF ROCKS BY DEEP FREEZING

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by

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SOURCE: UNKNOWN

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Increased effectiveness of mining can be achieved in several ways one of which is the decreasing of rock resistance to drilling

It is claimed /1/ that drilling velocity may be increased by 20 to 60% under the action of small quatities of certain "hardness reducing" substances such as sodium and magnesium chlorides, caustic soda, and other. However, this technique found no wide application and the recent trend in studying this problem is in the direction of high temperature effect on the rocks drilled. At the same time, the low temperature techniques have been little discussed and the effect of deep freezing remains practically uninvestigated.

The deep freezing effect on mechanical properties of metals has been studied to a greater detail. Very low temperatures increase the temporary resistance to compression and the yield point of many metals at the same time decreasing their capability of elongation and necking /2/; sudden lowering of impact strength leads to increased brittleness. Consequently, these metals fail under relatively small (compared to normal conditions) overstress such as the stress produced by dynamic loads, twisting, and bending. It is a well known fact, that maximum breakdown of mining transportation equipment occurs during winter.

The effect of low temperatures (-16°C) on physical and mechanical rock properties was studied in the Leningrad Mining Institute /2/ by determining temporary resistance to compression

of the granite, diabase, granite-gneiss, and sandstone samples subjected to 25 freezing-thawing cycles, heating to 400°C and cooling in moist sand; during this procedure the sample temperature was changed up to 50 times, passing through zero. The results indicated that the temporary compressive strength of the rocks was in some cases lowered to 43%.

Experimental investigation of compressive strength variation during heating and cooling (to -180°C) of sandstones, gabbro, graphite, and marble was conducted in the IGD laboratory (A. A. Skochinskii). The samples were cooled in liquid nitrogen for 20 to 25 minutes and tested in a hydraulic press with the following results: compressive strength of the samples has temporarily increased 1.75 times, which amounted to 11.4% for granites and 5.6% for marble.

It was concluded, that the temporary compressive strength of rocks, as well as of all solid bodies, is increased by deep freezing.

Apparently, like in metals, deep freezing would decrease rock ductility and its resistance to dynamic loads. This assumption was verified in the Noril'sk Mining and Metallurgical Combine in 1963 by studying the variation of rock mechanical properties under deep freezing.

Cylindrical samples were prepared from the cores of coarse- and fine-grained sandstones, gravely sandstone, and gabbro-diabase; they were tested in a pendulum ram-impact-machine at room temperature and in a cooled state. The samples were cooled for 30 minutes at 100 to 120°C below zero in a special bath filled with liquid

nitrogen mixed with alcohol.

Table 1 shows the results of sample cooling at various temperatures.

These results indicated that the amount of work needed for sample destruction has decreased by 4 to 4.5 times, i.e. rock strength (in this case - the impact viscosity) was decreased; the sample size was of no particular significance since the specific work of destruction was being determined.

At room temperature the amount of work needed for sample destruction varied within broad limits: from 1.5 to 3.2 kg.m/cm^2 but this range was narrower when the cooled samples were tested: o,37 to 0.55 kg.m/cm^2.

A similar experiment was made with 10 BK-15 metallo-ceramic plates of the form DB and the cross-section 2.13 cm^2 (GOST 880-48) to study the possible use of this effect in drilling. Five of the plates were tested at room temperature and five at -110 to -120^{o}C (Table 2).

Due to considerable scattering of the impact viscosity data it was impossible to definitely characterize the strength properties of this alloy subjected to deep cooling, but it was concluded that no sudden changes in the impact ductility of the alloy has taken place.

Thus, under normal conditions, there is a relatively small difference between the strength of the rocks and the strength of the rock-destroying instrument, but after a deep freeze of the rocks this difference increases several times, the instrument's strength remaining the same.

TABLE 1.

INDICES	Gabbro-diabase 1.	Gabbro-diabase 2.	Gravely sandstone 1.	Gravely sandstone 2	Coarse sandstone 1.	Coarse sandstone 2.	Fine sandstone 1.	Fine sandstone 2.
Sample diameter, cm	5.5	5.6	6.1	6.2	5.5	5.8	6.0	6.1
Height, cm........	3.7	3.6	2.7	2.8	2.9	2.7	3.5	3.3
Angle of pendulum declination, degree	50	95	32	64	52	78	43	82
Destruction energy $kg.m/cm^2$.........	2.3	0.5	1.5	0.37	3.2	0.55	1.8	0.45

Note: 1. - at room temperature; 2. - in a cool state.

TABLE 2.

Sample No.	Angle of pendulum declination, degree	Impact ductility, kg/cm^2
	AT ROOM TEMPERATURE	
1	75	3.7
2	50	2.2
3	42	1.7
4	95	4.9
5	37	1.4
	TEMPERATURE -100 to -120 $^{\circ}C$	
6	38	1.4
7	98	5.1
8	75	3.7
9	54	2.4
10	53	2.3

Note: Mean impact ductility of the samples No.1-5 is 2.7 $kg.m/cm^2$,
" No.6-10 2.9 kg.m/cm

The deep freezing effect on the physico-mechanical properties of rocks and the regularities governing this process, presently occur at the initial stage of investigations. The experimental results indicate the necessity of a broad experimentation in this domain of rock physics. It is recommended to start with the application of dynamic load (crushing, shearing, blasting) to deeply frozen rock samples. Besides, it is desirable to study the effect of a jet of liquid nitrogent (or other cooling substance) ejected at a supersonic speed, on the rocks - to determine the possibilities of "cryodrilling".

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